COREMAKING

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COMPLIMENTS OF
CORN PRODUCTS REFINING COMPANY
NEW YORK

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By

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To the Foundrymen:

So many of the losses in the Foundry due to imperfect castings can be laid to core-room practice, and so little has been done to study the several determining factors which are important for the perfect core for the work in hand, that we have sought to obtain for foundrymen authoritative information bearing upon core-room progress. To this end, we secured the services of Dr. Richard Moldenke, of international reputation in foundry work, to make a line of tests with various core-binders, sand mixtures, baking temperatures, etc., to aid the foundryman in judging the material he buys and in using the same most effectively.

The article presented herewith deserves the careful attention of all foundrymen. To make the booklet of additional value for reference, a collection of tables is included giving information useful, but frequently not at hand in convenient form. It is hoped that this publication may fill an existing need, and serve to awaken interest and investigation.

Respectfully,

Corn Products Refining Company.

Coremaking

by Dr. Richard Moldenke

ONE of the retarding influences in manufacturing enterprise is the ever present tendency to sacrifice quality to quantity production. This condition is noticeable in every line of business and is the cause of dissatisfaction and pecuniary loss to an extent but little realized. Every one interested thinks himself the one specially selected as the victim.

A manufacturer of molding machines who is honest enough to guarantee say one hundred and fifty molds, in figuring on a prospective order, will find himself in competition with a rival guaranteeing six hundred in equal time on his type of machine. The careful man loses the order and the foundryman, by the time he puts the remains of the over-rated machine in his cupola, fervently wishes he could put the builder in with it. No one is satisfied and all have lost out in some way.

The foundryman should not so much want to see a beautiful park of molds ready for pouring when the blast goes on, as that every one of the molds made will turn out a satisfactory casting. This pays in the end, and obviates the constant squabbles with molder and customer over imperfect work.

Good Castings

The elements entering into the making of a good casting may be summed up as follows: Good metal and fuel into the cupola; perfect melting and molding practice; good sand, cores, and above all proper gating; with these arranged for, the results should pass muster. A molding sand is good when of uniform grain size, the bond a fat refractory clay, and carrying a minimum of fluxing impurities. When properly tempered with water and judiciously rammed it forms a safe container for the molten metal. For greater resistance to the pressure and cutting action of the molten metal a mold may be dried. The strength of the sand structure goes up at once, the chances of failure from sand troubles diminish and the castings are more readily machinable.

The Core

A core is a body of sand placed in the mold to form a corresponding cavity in the casting. From this it will be noticed that

whereas the mold proper consists of compressed sand surrounding the molten metal poured in, the core is in the reverse situation; namely, a body of compressed sand almost entirely surrounded by molten metal. The sand surfaces of the mold allow the gases emanating from the setting metal, as well as the steam generated in the sand itself, to escape. In the case of the core, however, any steam or gases formed through contact of the molten metal with component parts subject to decomposition, must either be given free venting through the core itself to the atmosphere or else these gases will "kick" back into the metal and form a "blow," ruining the work.

Core Sand

The character of the sand used for a core must, therefore, be far more open than that for the mold itself. Indeed, small cores are usually made of sand free from all clay bond, and in the larger ones molding sand is added for the purpose of strengthening the core body. Since not more than a third of the core-mixture for large work may be molding sand, and even this of coarse structure, the strength of the result will be still far below that of the molding sand itself unmixed with sharp or fire sand free from bond. Imagine adding twice as much sharp sand to one of the sand-heaps on the molding floor, mixing thoroughly and then attempting to mold with this. If it is at all possible to hold the copes from dropping, the corners and edges of the mold will be quickly washed away by the molten metal in pouring.

The Binder

Nevertheless, for purposes of affording a sufficiently quick and safe exit for the gases through a core, this must be made of very open sand; clean, round, uniform-sized grains which cannot be packed together sufficiently to close up the spaces between them being most desirable. Manifestly, such a sand could not be held together without an added binding material strong enough in character to require but little of it so that the venting power of the core be not interfered with. The nature and method of applying such binders in core-making will be gone into more fully further on. Attention should be called at this point to the unusual strength requirements of cores as against those of the mold itself.

The Mold

The compressed sand of the mold is firmly held in wooden or preferably iron flasks provided with all kinds of cross-bars and similar devices to hold the sand in place before and

during the filling of the mold with the molten metal. This metal would then exert a pressure within the mold tending to compress the sand still further (swelling the casting) and also to lift the cope. It is naturally assumed that the cope is clamped tight upon the drag and that the entire flask is strong enough to resist deformation of any kind. The ferro-static pressure of the molten metal is a very patent thing to be reckoned with, as every molder who makes his first standard test bar mold will know. The bar is 1¼" diameter and 15" high—the bar being cast vertical with top pour. Usually the first few bars come out looking more like Indian clubs than the nice straight cylinders they should be. The sand of the lower portion of the mold has been compressed that much in addition to the regular ramming up by the molder.

In the core the foundryman has usually to deal with the powerful buoyant action of the molten metal exerted on long, comparatively thin-sectioned horizontal bodies of sand imbedded in the sides of the mold. Unless such cores are made of exceptionally strong sand and binder mixtures, and are in addition provided with heavy iron rods, they may readily bend upward in the centre or even break in two. The selection of the sand to be used and the core-binder to be added, therefore, is a vital issue in the foundry and to which the foundryman cannot give too much attention.

Sand Characteristics

So far as the sand is concerned, the ideal one is composed of round grains of equal size, these grains well finished by nature so that they may resist the action of heat without splitting up or crumbling. The finer the grain size, the smoother the surface the core will leave. On the other hand, the finer, the less the venting power. Hence the foundryman should select the finest grain he dare safely use. For large cores this means very coarse sand, even shading into fine gravel. Where the portions of the core which are imbedded in the mold to hold it in proper position are ample for good venting, the addition of molding sand is advisable, as this not only adds strength to the core but also may save binder—clay being nature's binder and far cheaper than any manufactured product. In most foundries the molds when shaken out yield so many large coreprints that it is necessary to use them over in the mixture in sheer self-defense—to hold down the bills for removal of the foundry dump. Core mixtures, therefore, are usually made up of core-sand (more or less free from clay bond), molding sand, and old cores which have been

crushed up. To these mixtures there is added the core-binder.

Cores are always made with the mixture in the damp state, the binder being either a liquid, such as linseed oil, or liquid binders thinned down with water, such as molasses-water; or dry binders mixed with the comparatively dry sand mixture, and then wet up to bring out the adhesive qualities of the binder. After ramming up the cores they must be baked. This operation consists of two distinct steps; first the actual drying, or evaporation of the water content, and then the baking proper. This gives the core its desired strength and removes as far as possible the component parts subject to destructive distillation when the molten iron touches it. The gas-making parts of the core being thus removed, there is still a final destruction of the binding substances required from the continued contact with molten iron, for the core must crumble and be easily removed from the recess it has formed in the casting.

Core Requirements

The service requirements of a good core may be summed up as follows:—It should stand up well enough in the green state to enable safe handling for baking. It must not swell or crack during baking, or soften and deform in storage within a reasonable time. The binder originally evenly distributed throughout the core should remain so and not draw to the skin sufficiently to endanger the result. A core should not soften, deform or "blow" during contact with molten iron before this has had time to set. It should crush easily after the casting has cooled and be readily rapped out.

Cores must be well vented, and are best not set into the mold unless this is pretty certain to be poured the same day. Molds that have been closed up and are not poured off should be opened up next morning to examine the cores for moisture, as these—particularly with binders requiring water to moisten or dilute them for use—are prone to re-absorb it if not changed in character by thorough baking.

Classes of Core Binders

The core binders in general use may be classified as follows:

- Water-soluble binders
- Paste binders
- Colloidal and allied bodies
- Gums and Pitches
- Oils

The foundryman ordinarily, however, classifies the binders as dry and liquid.

Binder Characteristics

The more important of the water-soluble binders are molasses, "hydrol" and the neutralized and concentrated waste sulphite liquors of the paper pulp process. Molasses is known to everyone. "Hydrol" is a syrup having the same relation to corn sugar that molasses has to cane sugar. The material on the market today should not be confounded with a former imported product ("hydrol"—oil soluble in water) which gave very poor and uncertain results as a core binder. The treated sulphite liquors above mentioned are much used in coremaking in conjunction with clay and other binders, and for their strength depend upon the soluble vegetable resins contained. The fact that the resins form but a very small part of the material accounts for the poor results obtained in the tests described later on when used with clean sand. The binder shows up better with molding sand additions.

In general, these binders are good so far as their adhesive properties are concerned, as in drying they draw to a point between the sand grains and thus cement them together. The two objections to the entire class, however, are the tendency of the binders to draw to the skin, leaving a weak interior, and the softening of the cores in damp places and within molds. The introduction of colloid substances, such as clay, counteracts the migratory tendency of the binder somewhat, and hence the use of molding sand in the core mixture.

Softening of Cores

The softening of the cores is a serious problem, for not only are lost castings to be reckoned with, but the storage of surplus stock becomes impossible. The difficulty is aggravated where the core-storage room is damp, of stone or concrete and apt to condense moisture from the air. Actual tests have shown that the trouble may be overcome by a proper baking of the cores. Underbaked cores will soften. On the other hand, overbaked cores are weak, and it therefore becomes a question of good core ovens and attention to the temperatures maintained in them. The driving off of the water in the soft cores requires time, but after this has been accomplished the baking itself is not a very long process. Core ovens on the down-draft principle work best. The core plates are put in near the bottom under the influence of the hot gases and air sweeping downward. The moisture is thus driven out and carried away in the bottom flues and up the stack. When dry the cores should be put into the upper part of the oven where the temperature is higher and be given the additional heat treatment to bake them well. If

the temperature of the lower portion of the oven be ke~ not less than 250 degrees F. and the upper regions (or in the case of linseed oil cores at 475 degrees satisfactory situation will be maintained. These temperatu can be raised somewhat if the men are alert enough to ta out the cores when properly baked. This hastens the proces Prolonged baking, however, under these conditions produce burnt and therefore weak cores.

In the tests to be described later, the broken cores were placed in a very damp cellar with concrete walls and floor. The underbaked cores were all affected more or less by the existing dampness, some of them flattening out badly. Where the maximum safe drying temperature had been reached, however, and where overstepped a little, the cores remained perfectly dry and safe to use in the mold. This indicates tha complaints about the core room can be obviated to a considerable extent, if not entirely, by proper attention to th oven construction and baking process.

Paste Binders

The paste binders are among the oldest and best known of all. Flour is still the old stand-by in many shops, but ha the objection that unless sparingly used the cores will swell Further, in baking, the acrid smoke evolved is almost insupportable where the ventilation is poor. The development of this class of binders has, therefore, run in the direction of separating the essential binding principle from the inert parts of the cereals used, and putting this concentrated adhesive material into the dry binders of commerce.

Probably the best of all dry binders are those having a *dextrin* base. When properly manufactured and proportioned these binders are so strong that but little is required in the core mixture and hence in baking the smoke and annoyance incident to the use of flour in poorly designed ovens, is done away with practically altogether. To utilize these binders to the fullest advantage the core-mixture should be tempered up in the afternoon previous to use. This will thoroughly soften the binder and allow it to spread evenly and thinly between the grains of the sand, giving much of the effect obtained with the water-soluble binders. A second mixing in the morning completes the preparation of the batch and breaks up all lumps, leaving a fine uniform mixture for the work in hand.

The disadvantage of the group is the tendency to draw moisture if not properly baked, though not to as serious an extent as with the water-soluble binders. The growing de-

mands upon the core room, particularly when larger classes of work are made necessary by the advent of the jarring machine and molds made up almost entirely of cores, must result in greater attention to this rather neglected foundry department. Among other things, cores will be baked at proper temperatures after the moisture contained has been entirely removed, so that they do not come out with hard, brown surfaces and a soft interior. Attention will also be given to blacking materials so that the carrying medium may incidentally act as a protection along the lines of waterproofing. In the meantime, however, foundrymen should see that the core-drying capacity is well ahead of their requirements, so that the work need not be rushed unduly.

Other Binders

The Colloidal bodies derive their binding power from the glue or jelly-like constituents they contain. Clay is the best of them. Manure, magnesia, aluminum and iron compounds find their application in some measure in foundry specialty work. But after all, clay fills the bill best and its presence in molding sand makes this the desirable medium for adding strength to the core mixture so long as the venting power of the finished core is not interfered with too seriously.

The Gums and Pitches are best represented by rosin for the first named, and the tars entering the so-called black compounds for the latter. Rosin, when melting, will run about the grains and cement them together on cooling. As it does not bind the core when green, other substances must be used. Clay may be sufficient, but usually flour or a better grade paste binder has to be added to the mixture to enable the use of rosin at all. The constantly rising cost of the gums is steadily making them too expensive for coremaking purposes. The pitches are particularly good for the larger classes of cores, but as they carbonize under the influence of molten iron they give much difficulty in the cleaning room. This has, therefore, to be reckoned with when using them in sufficient quantity to give satisfactory results.

The best representative of the oil group is Linseed Oil. It is rarely obtained by foundries in the pure state, but is adulterated, if not entirely replaced in many instances by other cheaper vegetable and mineral oils. The fact that this oil depends upon a rapid oxidation of the thin films covering the sand grains for its binding power emphasizes the necessity of a thorough circulation of hot air in the drying ovens. The core is really held together by a very thinly distributed paint, as it were. Hence also the great number and high percent-

ages of drying adulterants used to "improve" a binder which would be most excellent if furnished pure. The solutions of gums and resins in petroleum, the asphaltic base residues of crude oil, and many other oils having a mixed mineral and vegetable origin come within this group.

Selection of Binder

The choice between liquid and dry binders lies in the nature of the core to be made. As previously stated, the liquid binders have a strong tendency to migrate to the surface. The thicker the core the more time necessary to bake it properly; and therefore the greater the quantity of binder collected at the skin of the core. The consequence is, that with heavy cores the situation may become so serious that not only will the molten iron flow over a surface as dense and impenetrable as stone, but in the charring of the binder considerable gas is formed which can only escape backward by "blowing" into the iron. The result is always a lost casting. On the other hand, with very thin cores, the oxidation of the oil is more rapid and thorough and migration of the oil is retarded. Liquid binders are therefore applied to very light section cores, whether these be large or small. Or, if used for heavier work, molding sand is added to help retard the oil migration mentioned.

Dry binders, on the other hand, particularly if mixed with the sand as previously described, remain evenly distributed in the mass of the core and hence make it equally strong as well as permeable to air and gases throughout. The customary practice of using more dry binder than would be the case with the liquid varieties is readily shown to be illusive if the mixing is done properly. The binder after softening up all night on reworking in the morning is spread very thinly between the sand grains, and hence much less binder will give satisfactory results than where the mixture is used directly after putting the ingredients together. Indeed, the foundryman who avoids this extra labor simply damages his pocket in the long run by using an excessive quantity of binder or else losing castings. Further, by employing proper mixing machines he will get better metal surfaces and please his customers, besides saving on the binder used.

Attention should be called to the mistake often made in mixing oil and paste binders. The latter are baked properly at about 350 degrees F., whereas linseed oil requires about 450. Either the full value of the oil will not have been obtained when baking for the paste binder, or the latter will be ruined if baking for the oil.

It will not be necessary to go into the details of coremaking, such as filling the interior of large structures with coke, and making use of wax vent wires or tapers, the details of rodding and the use of arbors, grids, dryers for baking delicate cores, etc. Nor will the pasting of cores and slurrying the joints need special attention here, as foundrymen are entirely familiar with these things, and if they know their business will give mighty close attention to them. What the average foundryman, however, needs badly and has little time or practice in working out, is a series of comparable tests on core binders based upon some unit of performance known to the trade generally. With this he can make his own test of the binder he contemplates purchasing, or is getting from time to time, and can figure out the relative economy. Thus, if he has to pay a certain price for linseed oil, and can get equal strength and better results with another binder for less money, he would certainly be asleep if he did not take advantage of the situation. It is a mistake to keep on using a material that can be replaced by a more economical product if the latter gives equal or even better service. In the development of civilization there is room for everything and a material replaced in one industry finds its application in another, and probably to better advantage. The producer is not only constantly at work improving his product—otherwise his business dies of dry-rot—but he is also searching the world for new markets. The foundryman who does not do the same, will fall behind in the race.

Core Tests

To aid the foundryman in valuing core binders, a series of tests has been undertaken with characteristic representatives of the various classes of core binders discussed. To note the binding effect on the sand, two lines were followed. First, using an all silica sand—in this case "sea sand" was selected; and second, a mixture of this sea sand three parts, with one part of "Lumberton" molding sand. The molding sand was of medium grade of fineness. The all-silica sand group would correspond to the smaller range of cores, and the molding sand mixture to the heavier lines.

The proportions of binder used were the following: One binder to fifteen sand, to illustrate the use of excessive quantities of binder. Next, one binder to twenty-five sand, to correspond with ordinary practice requiring fairly good strengths. Then, one binder to fifty sand, which would be called quite economical. Finally, one binder to one hundred sand, as an example of extreme economy and, unless great

care is used, rather beyond the line of safe practice. Indeed, when using linseed oil in this proportion it was impossible to get the cores to hold their shape when first made in the case of the molding sand mixture until this had first been tempered with water. The extremely small quantity of oil was absorbed by the clay content and prevented from exerting any adhesive action. Even in the case of the sea-sand, or all-silica material, the mixture had to remain unused for a while to allow the oxidation of the oil to begin. The cores could then be made and gave good results in spite of the minute quantity of oil used.

Since all the binders other than linseed oil (and even this for the molding sand mixture) were used in connection with sufficient water to properly temper the sand, no trouble was experienced in making the cores in the usual manner of the shop. The core mixtures were all allowed to stand a while before using to aid in the attainment of uniformity of moisture and the proper softening of the dry binders.

After drying and baking in an electric drying oven, the upper and rear portion of which was kept at the maximum temperature given in the tables, and the lower part above 225 degrees F.—the core plates full of cores being shifted from the bottom upward during the process of baking—the cores made were subjected to a transverse breaking test. The cores were all 1 inch square and seven inches long. When placed on supports six inches apart and the load applied centrally, the figures given in the tables to follow were obtained. The temperatures may be taken as approximate only, but are near enough to be correct for practical purposes. The strength is given in pounds, and as a whole the tables show some very interesting figures.

The binders used were "Hydrol," Molasses, Waste Sulphite, Liquor Concentrates, for the liquid binders. "Kordek," a dextrine and starch product made from corn, and Flour (wheat) represented the paste binders. Rosin (used with equal parts of flour) was selected as a type for the gums. Linseed oil, representing the oils, completed the list. It may be stated that the linseed oil used was absolutely pure and obtained from the original producer. In the case of the rosin and flour cores, the binder proportions refer to half flour and half rosin in each case. Thus, for one part binder to fifty sand, this means one-half flour and one-half rosin to fifty sand.

The tables of results now follow:

Linseed Oil

Transverse strength of 1″ square Cores broken on supports 6″ apart

Approximate Temperature Degrees F.	All Core Sand Binder and Sand Proportions				Core Sand 3, Molding Sand 1 Binder and Sand Mixture Proportions			
	1 : 15	1 : 25	1 : 50	1 : 100	1 : 15	1 : 25	1 : 50	1 : 100
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
275	13.73	9.21	4.44	3.45	17.75	13.26	10.30	4.12
300	15.11	11.90	7.79	3.99	17.36	14.19	10.80	4.14
325	15.18	12.61	11.55	4.81	22.79	16.04	13.73	5.06
350	16.50	15.18	13.97	4.77	30.95	17.62	17.58	5.52
375	19.89	22.70	20.83	8.45	35.05	30.21	23.54	9.77
400	48.00	32.27	22.33	9.02	48.62	32.67	26.49	11.80
425	55.39	36.19	36.93	10.82	72.93	54.98	36.10	12.53
450	78.94	49.99	40.42	11.07	84.92	60.43	44.97	12.68
475	45.63	36.74	25.26	5.98	47.26	35.44	37.73	4.80

"Kordek"

Transverse strength of 1″ square Cores broken on supports 6″ apart.

Approximate Temperature Degrees F.	All Core Sand Binder and Sand Proportions				Core Sand 3, Molding Sand 1 Binder and Sand Mixture Proportions			
	1 : 15	1 : 25	1 : 50	1 : 100	1 : 15	1 :25	1: 50	1 : 100
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
275	12.18	10.02	4.50	3.03	26.28	20.26	10.12	7.80
300	18.64	14.76	8.70	7.16	47.60	37.40	15.04	11.70
325	21.45	16.10	11.27	8.61	60.39	45.54	17.54	11.22
350	24.90	18.79	13.60	9.82	62.10	45.77	16.57	12.24
375	15.25	12.00	9.83	6.75	19.14	16.38	8.43	8.88

"Hydrol"

Transverse strength of 1″ square Cores broken on supports 6″ apart.

Approximate Temperature Degrees F.	All Core Sand Binder and Sand Proportions				Core Sand 3, Molding Sand 1 Binder and Sand Mixture Proportions			
	1 : 15	1 : 25	1 : 50	1 : 100	1 : 15	1 : 25	1 : 50	1 : 100
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
275	22.60	14.47	8.44	7.22	38.15	20.67	9.33	6.43
300	41.82	17.36	16.08	10.70	54.78	25.08	10.41	7.00
325	55.44	40.94	21.77	18.14	62.28	27.45	15.90	8.60
350	66.78	47.20	25.40	20.53	66.42	33.66	16.86	10.22
375	57.08	44.81	22.10	15.62	59.11	28.80	14.70	9.14

Molasses

Transverse strength of 1″ square Cores broken on supports 6″ apart.

Approximate Temperature Degrees F.	All Core Sand Binder and Sand Proportions				Core Sand 3, Molding Sand 1 Binder and Sand Mixture Proportions			
	1 : 15	1 : 25	1 : 50	1 : 100	1 : 15	1 : 25	1 : 50	1 : 100
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
275	12.26	8.12	6.53	5.17	12.08	6.58	3.96	3.59
300	18.77	13.79	7.92	6.40	15.14	9.22	5.87	6.02
325	26.40	15.60	8.14	7.19	19.38	11.74	7.41	6.40
350	26.80	18.06	9.94	8.36	22.70	13.46	8.20	6.68
375	25.08	14.07	9.06	8.27	15.42	8.72	5.54	4.70

Waste Sulphite Liquor Concentrates

Transverse strength of 1″ square Cores broken on supports 6″ apart.

Approximate Temperature Degrees F.	All Core Sand Binder and Sand Proportions				Core Sand 3, Molding Sand 1 Binder and Sand Mixture Proportions	
	1 : 15	1 : 25	1 : 50	1 : 100	1 : 50	1 : 100
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
275	2.10	1.32	0.76	0.24	8.20	3.02
300	2.58	1.75	1.13	0.98	13.80	5.44
325	3.47	2.80	1.87	1.20	14.52	7.81
350	3.81	3.17	2.19	1.52	14.80	8.33
375	2.90	2.05	1.41	0.65	13.14	6.65

Rosin and Flour

Transverse strength of 1″ square Cores broken on supports 6″ apart.

Approximate Temperature Degrees F.	All Core Sand Binder and Sand Proportions	Core Sand 3, Molding Sand 1 Binder and Sand Mixture Proportions
	1 : 50	1 : 50
	lbs.	lbs.
275	16.68	7.41
300	23.76	16.84
325	24.08	17.50
350	21.16	17.18

Flour

Transverse strength of 1″ square Cores broken on supports 6″ apart

Approximate Temperature Degrees F.	All Core Sand Binder and Sand Proportions	Core Sand 3, Molding Sand 1 Binder and Sand Mixture Proportions
	1 : 50	1 : 50
	lbs.	lbs.
275	12.77	8.98
300	16.20	16.59
325	19.80	17.40
350	18.64	17.21

Discussion of Tests

A study of the figures shows the following characteristics: That there is a best temperature for baking in each case. This temperature, however, can go up and down for some distance before the value of the cores are seriously impaired. For linseed oil 450 degrees F. shows the best strength, the higher ranges of heat beginning to destroy the binding property. This is as it should be, for a core is supposed to be gradually charred by the iron which has set about it in the process of pouring the mold. The dextrine binder ("Kordek") exhibited this property best of all, the carbonization being quite pronounced as the heat was run above the 400° point.

The water-soluble binders gave the best results at 350 degrees F., but were sufficiently strong from 300° to 375°. The proper point, however, would lie between 350° and 375°, for at the lower temperatures, in spite of showing good strength, the subsequent softening of the core by moisture absorption was found to be a decided detriment for storage purposes or retention in a mold over-night. In the case of a core with flour, the proper temperature ran lower, as 325 degrees F. shows up best. The dextrine binder ("Kordek") could be baked as high as the water-soluble binders safely, and of all the binders tried gave the least trouble from smoke and gases; in fact, these were hardly noticeable. The flour cores, and especially those with linseed oil, were a positive torture to every one near during the baking process.

Before discussing the differences between the all-silica sand results and those from the sand mixture containing molding sand, it may be stated that the strength of the latter mixture (sea-sand 3 and molding sand 1) without a binder was obtained first. The material was tempered with water just

as in making a sand heap for molding purposes (7½ per cent. water being the amount used); the cores dried in the oven, and then tested just as for the regular series. The average strength, on cross-breaking, of a number of these dry sand bars was 0.80 lbs. This amount represents the strength imparted to the core by the clay content of the molding sand used, but evidently has nothing to do with the effect of the clay on the binders used in the regular tests, as the results show widely varying figures. In the case of linseed oil, "Kordek," and particularly the waste sulphite liquor, the strength of the cores made with molding sand in the mixture is higher than without it. The other binders, however, show exactly the reverse. This would indicate that mixing various types of binders must be watched, as the results may be poorer than if each binder had been used alone. Clay is a binder of the colloid type, and in these tests it has helped the strength in some cases and hurt it in others.

Taking the binders individually, there will be noticed that linseed oil gives astonishingly fine results. This is because it happens to be the pure article, little of which finds its way into the foundry today. The linseed oil—sea sand, 1: 50 core, no molding sand and baked at 450° F. has been taken as the standard for comparison and called 1.00. The other binder results as related to this standard will be shown in a table further down.

The "Kordek" results, while not as strong as those with linseed oil, are quite high, justifying the prevailing impression that dextrine is one of the best of binders known. Unquestionably this binder would show far higher results in comparison with the "linseed oil" that gets into the foundries today. The results in the table show that the strengths are good from 300 degrees F. up. The higher ranges are safest for the moisture problem, hence where cores are to be stored—the general custom being to make up to 10 per cent. over the order—the darker ones should be selected for that purpose.

"Hydrol" exhibits remarkable strength for a liquid binder, much of this being probably due to the general tendency of wet binders to draw to the surface. With rapid baking this tendency is counteracted somewhat, and when the higher safe temperatures are reached, the cores stand up excellently. "Hydrol" being a corn sugar molasses is destined to replace the regular cane sugar molasses to a great extent, as it becomes better known. A glance at the tables will show the reason. At the present moment, with the imminent prospect of the withdrawal of the country's entire supply of molasses for

munition purposes, it will pay foundrymen to try out this comparatively recent candidate for foundry favor.

In the case of molasses, the difference between the two lines of sand is not serious. On looking at the waste sulphite liquor figures, however, one is astonished to see how poor they are for the sea-sand cores and how improved the results become when molding sand is added to the mixture.

The rosin and flour, as also the flour alone, show up good strength. These are old-time binders known to every foundryman. Rosin is now too expensive to find its way into the core room, and flour is only good when in first-class condition. The flour used in these tests did not consist of "sweepings," but is genuine wheat flour bought at the ordinary grocery. This accounts for the unusually high results obtained from flour, and flour and rosin, as compared with Kordek. At the present moment, the use of flour in the foundry is out of the question, both on account of food regulations and for patriotic reasons. The flour figures, therefore are of only secondary interest.

The table above mentioned, showing the relative value of the binders, the cores being taken at their best baking temperatures, and the comparison made with linseed oil—sand 1: 50, as above stated, now follows:

Table

Comparative value of Core Binders. Linseed Oil-Core Sand 1:50 (at 450° F.) equals 1.00

Binder	Baking Temperature Degrees	All Core Sand				Core Sand 3, Molding Sand 1			
		Binder and Sand Proportions				Binder and Sand Mixture Proportions			
	F.	1 : 15	1 : 25	1 : 50	1 :100	1 : 15	1 : 25	1 : 50	1 :100
Linseed Oil..	450	1.95	1.23	1.00	0.27	2.10	1.49	1.11	0.31
Kordek......	350	0.62	0.46	0.34	0.24	1.53	1.13	0.41	0.33
Hydrol......	350	1.65	1.17	0.63	0.57	1.64	0.83	0.42	0.25
Molasses.....	350	0.66	0.45	0.25	0.21	0.56	0.44	0.20	0.17
Sulphite Liq..	350	0.09	0.08	0.05	0.04	.....	.....	0.37	0.21
Rosin & Flour	325	.....	.....	0.60	.....	.....	.....	0.43	.....
Flour........	325	.....	.....	0.49	.....	.....	.....	0.43	.....

Discussion of Table of Comparative Values

A few words are necessary in regard to the 1 : 15 and 1 : 100 data. These are the exceptional cases in coremaking, the general run of work being found in a range from 1 : 25 down to 1 : 50 binder and sand. Nevertheless, in radiator

work or where cores must be readily destroyed and shaken out in cleaning, the very dilute mixtures of strong binders find ready application.

Foundries are not apt to buy flour in competition with bakeries, and rosin is too expensive. The smoke from flour after pouring is now subject to sanitary code regulations. Hence, in selecting a binder, the choice would be made from pure linseed oil, if obtainable at reasonable cost, Kordek, hydrol and molasses, for cores made without molding sand; and the waste sulphite liquors in addition to the above list for cores made with molding sand. Taking into consideration the cost of pure linseed oil and the trouble from moisture absorption on the part of the water-soluble binders, the dextrine binder, Kordek, remains as best adapted for the general run of cores.

For the practical range of binders (1:25 down to 1:50) *pure* linseed oil still holds the palm for strength, but after this it will be noted that Kordek and Hydrol give the best results for the dry and wet binders, respectively, both in straight sand and molding sand mixtures. This is easily understood when it is remembered that Kordek is essentially a dextrinized corn flour, while hydrol is a more highly concentrated corn sugar molasses than the regular cane sugar molasses of commerce. They bear out the statement previously made that modern developments run in the direction of eliminating the unessential portions of binders to save materials, costs, and subsequent baking difficulties and annoyances.

For weights and costs the following figures may be of value to the foundryman in comparing the dry and wet binders. The determinations were made on the actual materials used in the tests in question.

Material	Specific Gravity	Weight per gallon in pounds
Water	1.000	8.34
Linseed Oil	0.934	7.79
Waste Sulphite Liquor Conc.	1.258	10.49
Molasses	1.263	10.53
Hydrol	1.401	11.68

A final matter of interest may be given as the result of subjecting all the cores made to a microscopic examination. The structure of the cores of both sand mixtures was seen

to be extremely open—as it should be for proper venting. The grains of sand being rounded in a measure were forced into contact with each other at their flatter surfaces, and here the core binder cemented them together—a thin film for the poor mixtures and an "I" shaped cement like joint for the rich ones. It was further observed that for both wet and dry binders each grain of sand was coated with the binder all over its surface, showing that the bulk of the binder is wasted in coremaking.

A further interesting observance was that the clay content of the molding sand used in the mixtures for half the tests evidently united with the binder by reason of the common vehicle—water—and separated from the sand grains sufficiently to form part of the cementing bond between them. This may explain why some binders gave stronger results with molding sand additions and others gave weaker ones. Some binders may have been absorbed by the clay to the detriment of their adhesiveness, whereas others may have been thickened by the clay addition and worked into points between the sand grains rather than spreading evenly over them.

The general impression resulting from the rather elaborate series of tests above described would seem to be that the core room presents problems far more serious than is generally supposed. In estimating on castings to be made the foundryman always considers the amount of core work first. If he had his core room equipped as it should be, his binders and mixtures on a rational, economical and sound basis for strength, venting quality, etc., he would not have to worry so much about the costs for that particular end of his shop. The labor end is simple as compared with the molding floor, but the very ignorance of the fundamentals in coremaking has caused the core room to be the unreasonably expensive end of the foundry industry.

Tables

Recommended Analyses for Various Classes of Castings

Castings	Light					Medium					Heavy				
	Si	Mn	S	P	T.C.	Si	Mn	S	P	T.C.	Si	Mn	S	P	T.C.
Acid-resisting	2.00	0.75	0.05*	0.20*	3.25*	1.50	1.25	0.05*	0.20*	3.25*	1.00	1.25	0.05*	0.20*	3.25*
Agricultural	2.50	.60	.06	.75	3.75	2.25	.70	.08	.70	3.50	2.00	.80	.10	.60	3.25
Air Cylinders	1.90	.70	.08	.50	3.40	1.50	.80	.09	.40	3.25	1.00	.90	.10	.30	3.00
Annealing Boxes	.....	.....	.....	.....	.....	.65	.20	.08	.20	3.50	.....	.....	.....	.....	.....
Automobile Cylinders	2.25	.65	.08*	.40*	3.25*	2.00	.75	.08*	.40*	3.25*	.....	.....	.....	.....	.....
Balls for Grinding	.....	.....	.....	.....	.....	.75	.50†	.15*	.40*	3.75†	.50	.50†	.15*	.40*	3.75†
Bed Plates	2.00	.70	.08	.60	3.75	1.75	.75	.10	.50	3.50	1.50	.80	.12	.40	3.25
Boiler Castings	.....	.....	.....	.....	.....	2.00	.80	.06*	.20*	3.50*	.....	.....	.....	.....	.....
Car Wheels	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.65	.50	.08	.35	3.50
Chilled Castings	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.00	.06*	.20*	3.50*
Chills	.....	.....	.....	.....	.....	1.00	.50	.05	.20	3.00	.....	.....	.....	.....	.....
Crusher Jaws	.....	.....	.....	.....	.....	1.00	1.00	.04	.20	3.50	.80	1.25	.06	.20	3.25
Dies for Hammers	.....	.....	.....	.....	.....	1.50	.60	.05	.20	3.00	1.25	.80	.06	.20	2.75
Dynamo Castings	2.50	.50	.05	.75	3.75	.....	.....	.....	.....	.....	2.15	.50	.06	.50	3.25
Electrical Work	3.00	.50	.03	.60	3.75	2.75	.50	.05	.50	3.50	.....	.....	.....	.....	.....
Engine Frames	.....	.....	.....	.....	.....	2.00	.60	.08	.50	3.50	1.75	1.00	.10	.40	3.00
Fire Pots, Grates	2.25	.60	.05	.20	3.50	2.00	.80	.06	.20	3.25	.....	.....	.....	.....	.....
Fly Wheels	2.00	.50	.05	.50	3.50	1.50	.60	.06	.40	3.25	1.25	.70	.08	.30	3.25
Friction Clutches	2.40	.60	.10	.70	3.75	2.00	.70	.12	.50	3.50	.....	.....	.....	.....	.....
Furnace Castings	2.40	.60	.05	.60	3.75	2.15	.80	.06	.50	3.50	.....	.....	.....	.....	.....
Gas Engine Cylinders	2.00	.70	.08	.40	3.25	1.50	.80	.09	.30	3.00	1.25	.90	.10	.20	2.85

*Below.

† Above.

From Moldenke, "Principles of Iron Founding."

Recommended Analyses for Various Classes of Castings (*Continued*)

Castings	Light					Medium					Heavy				
	Si	Mn	S	P	T.C.	Si	Mn	S	P	T.C.	Si	Mn	S	P	T.C.
Gears	2.25	.60	.08	.70	3.75	2.00	.80	.09	.60	3.50	1.50	1.00	.10	.50	3.25
Glass Molds, Pipe Balls	.....	.....	.....	.....	.....	2.50	.60	.04	.20	3.25	.....	.....	.....	.....	.....
Grate Bars	.....	.....	.....	.....	.....	2.00	.60	.05	.20	3.50	.....	.....	.....	.....	.....
Gun Iron	.....	.....	.....	.....	.....	1.50	.50	.05	.30	3.25	1.00	.60	.05	.30	3.00
Hardware	2.50	.70	.08	.80	3.75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Heat-resistant Iron	.....	.....	.....	.....	.....	2.00	.80	.06	.20	3.25	1.50	1.00	.06	.20	3.00
Hydraulic Cylinders	.....	.....	.....	.....	.....	1.50	.80	.05	.40	3.25	1.00	1.00	.08	.20	2.85
Ingot Molds	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.25	.80	.06	.20	3.75
Machinery Castings	2.50	.60	.08	.70	3.75	2.00	.80	.09	.60	3.50	1.50	1.00	.10	.50	3.25
Mine Wheels	.....	.....	.....	.....	.....	.90	1.00	.10	.20	3.00	.....	.....	.....	.....	.....
Ornamental Castings	2.75	.60	.06	.90	3.75	2.25	.70	.08	.80	3.50	.....	.....	.....	.....	.....
Pipe (Water)	2.25	.60	.06	.80	3.75	2.00	.80	.08	.70	3.50	1.50	1.00	.10	.60	3.50
Piston Rings	2.00	.70	.05	.60	3.50	1.75	.80	.06	.50	3.25	.....	.....	.....	.....	.....
Pulleys	2.40	.50	.05	.70	3.75	2.15	.60	.07	.60	3.50	1.90	.70	.09	.50	3.25
Radiators	2.25	.70	.06	.80	3.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Rolls (Chilled)	.....	.....	.....	.....	.....	.....	.80	.06	.40	3.25	.....	1.00	.08	.30	3.00
Soft Castings	2.60	.50	.06	.60	3.75	2.40	.60	.08	.50	3.50	.....	.....	.....	.....	.....
Soil Pipe	2.25	.60	.08	.80	3.75	2.00	.80	.10	.60	3.50	.....	.....	.....	.....	.....
Steam Cylinders	2.00	.60	.08	.50	3.50	1.60	.80	.09	.40	3.50	1.25	1.00	.10	.30	3.50
Stove Plate	2.50	.50	.06	1.00	3.75	2.25	.60	.08	.80	3.50	.....	.....	.....	.....	.....
Valves	2.25	.60	.07	.50	3.25	1.75	.80	.08	.40	3.00	1.25	1.00	.09	.30	2.85
White Iron Castings	.....	.....	.....	.....	.....	.75*	.20†	.25*	.75*	2.50†	.....	.....	.....	.....	.....

* Below.

† Above.

From Moldenke. "Principles of Iron Founding."

Weight of Cast Iron

Variety	Specific Gravity	Lbs. per cu. ft.
Coarse-grained gray pig iron......	6.80	425
Coarse-grained gray cast iron......	7.00	437
Fine-grained cast iron............	7.20	449
Mottled pig iron..................	7.64	477
White pig iron....................	7.69	480
White, charcoal, high P. cast iron..	7.80	487
Average gray iron.................	7.10	443
Average white iron................	7.50	468
Very open gray coke pig iron......	6.79	....
This remelted in air furnace.......	7.50	....
Cold-blast coke pig iron...........	7.07	....
This remelted in air furnace.......	7.68	....
Gray charcoal pig iron for malleable	7.06	....
This remelted in air furnace.......	7.52	....
Gray charcoal pig iron—sand cast.	7.15	....
This iron—machine cast..........	7.53	....
Gray interior of chilled roll........	7.06	....
Chilled portion near surface.......	7.52	....

From Moldenke, "Principles of Iron Founding."

Melting Points of Cast Iron, Brass, etc.

Name	Composition	Melting Point Degrees F.	Authority
Brass	Copper 95 Zinc 5...........	1,960	Shepherd
	" 90 " 10..........	1,930	"
	" 85 " 15..........	1,880	"
	" 80 " 20..........	1,830	"
	" 75 " 25..........	1,795	"
	" 70 " 30..........	1,725	"
	" 65 " 35..........	1,660	"
	" 60 " 40..........	1,635	"
Bronze	Copper 95 Tin 5.........	1,920	Shepherd
	" 90 " 10.........	1,840	"
	" 85 " 15.........	1,760	"
	" 80 " 20.........	1,635	"

Melting Points of Cast Iron, Brass, etc. (*Continued*)

Name	Composition	Melting Point Degrees F.	Authority
Cast Iron	Average gray	2,260	Moldenke
	" white	2,100	"
Solder			
Soft	Tin 1 Lead 3	482	Brannt
	" 1 " 2	411	"
	" 1 " 1	370	"
	" 2 " 1	340	"
	" 3 " 1	356	"
Steel	Low carbon	2,685	Le Chatelier
	Medium carbon	2,650	"
	High carbon	2,570	"

From Various Sources. See also Fusible metals, Physics and Chemistry of Foundry metals, etc.

Contraction Allowance for Various Metals and Alloys

Name	Contraction in Sixty-fourths Inch per Foot
Ferrous Metals:—	
Steel	16
White Iron	16 to 12
Mottled Iron	9
Light Gray Iron	9 to 6
Medium Gray Iron	8
Malleable Cast Iron	8
Columns of Cast Iron	7
Cylinder and Engine Frames (large)	6
Heavy Gray Iron	5
Non-Ferrous Metals and Alloys:	
Aluminum	14
Copper	14
Brass	14 to 12
Bronze	12
Zinc	12
Lead	12
Tin	10
Bismuth	5

From Moldenke, "Practice of Iron Founding" (advance sheets).

Estimating Weight of Castings from Pattern

Material of Pattern	Multiply Weight of Pattern by	Sp. Gr. of Material
Cedar	17.5	0.40
Red Wood	17.0	0.42
Poplar	15.8	0.45
Cypress	14.8	0.48
White Pine	14.2	0.50
Birch	13.0	0.55
Yellow Pine	11.6	0.61
Ash	11.1	0.64
Cherry	11.0	0.65
Chestnut	10.9	0.66
Maple	10.4	0.68
Black Walnut	10.0	0.70
Elm	10.0	0.72
Beech	10.0	0.72
Red Oak	9.6	0.74
White Oak	9.2	0.78
Hard Mahogany	8.3	0.85
Hard Rubber	7.3	0.97
Red Fibre	5.1	1.40
Plaster Paris	3.1	2.27
Aluminum (cast)	2.60	2.80
Zinc	1.00	7.10
Tin	0.97	7.29
Brass (yellow)	0.85	8.37
Copper	0.83	8.50
Bronze (gun metal)	0.82	8.67
Lead	0.63	11.35

From Moldenke, "Practice of Iron Founding" (advance sheets).

Cupola Melting Loss

Material	Per Cent. Loss
Machine-cast Pig Iron....................	0.30
Sand-cast Pig Iron........................	1.00
Car Wheels................................	2.00
First Quality Machinery Scrap............	2.50
Light Machinery Scrap....................	3.50
Stove Plate Scrap........................	8.00

From Moldenke, "Principles of Iron Founding."

Composition of Molding Sands
Rational Analyses—Averages

Region	Quartz	Clay Substance	Feldspar
New York (Albany)..........	58.82	18.99	22.16
Kentucky..................	64.53	24.77	10.69
Ohio......................	71.02	23.79	5.17
Missouri..................	64.10	24.36	11.54
Pennsylvania..............	67.21	21.99	10.79
New Jersey................	81.38	15.49	3.13
Illinois..................	70.82	16.65	12.53
Georgia...................	77.37	17.94	4.69
Tennessee.................	74.53	21.11	4.36
Grand Average..............	65.53	21.73	12.74

Recalculated for Ultimate Composition:

Silica....................................	84.26
Alumina (and Iron Oxide)..................	13.59
Lime, Alkalies, etc.......................	2.15

From Moldenke, "Principles of Iron Founding."

Rational Melting Capacities of Cupolas

Cupola Diameter, inside lining (inches)	Tons melted per hour	Cu. ft. blast required per minute
18	0.5	250
24	1.5	750
30	3	1,500
36	4.5	2,250
42	6	3,000
48	8	4,000
54	10	5,000
60	13	6,500
66	16	8,000
72	19	9,500
78	22	11,000
84	26	13,000
90	30	15,000

Blast volume required to melt one ton of iron is taken at 30,000 cu. ft.

To get speed of Positive Blower, divide the cu. ft. blast required per minute by the cu. ft. air of blower per revolution.

From Moldenke, "Principles of Iron Founding."

Composition of Various Alloys by Name

Name	Copper	Zinc	Tin	Lead	Aluminum	Iron	Other Metals
Admiralty Metal	87.0	5.0	8.0	.....	.....	.....	.....
Aich's Metal	60.0	38.2	.....	.....	.....	1.8	.....
Ajax Metal	81.2	.....	11.0	7.8	.....	.....	.....
Aluminum-copper Alloy	7.5	.....	.....	.....	92.5	.....	.....
Aluminum-zinc Alloy	.....	35.0	.....	.....	65.0	.....	.....
Arguzoid	48.5	31.0	.....	.....	.....	.....	Nickel 20.5
Arsenic Bronze	82.2	.....	10.0	7.0	.....	.....	Arsenic 0.8
Bath Metal	80.0	20.0	.....	.....	.....	.....	.....
Bell Metal	80.0	20.0	.....	.....	.....	.....	.....
Bobierre's Metal	66.0	34.0	.....	.....	.....	.....	.....
Bristol Brass	72.8	27.0	.....	0.2	.....	.....	.....
Camelia Metal	70.2	10.2	4.3	14.8	.....	0.5	.....
Cartridge Brass	66.7	33.3	.....	.....	.....	.....	.....
Clock Brass	60.0	40.0	.....	.....	.....	.....	.....
Constantan	60.0	.....	.....	.....	.....	.....	Nickel 40.0

Composition of Various Alloys by Name (*Continued*)

Name	Copper	Zinc	Tin	Lead	Alum-inum	Iron	Other Metals
Cornish Bronze....	77.8	.....	9.6	12.6	.....	.....	....
Cyprus Bronze.....	65.0	30.0	5.0	.....	.....	.....	....
Damascus Bronze..	76.8	.....	10.6	12.6	.....	.....	....
Delta Metal.......	57.5	40.0	.....	.....	.....	2.5	....
Demo Bronze......	64.0	30.0	5.0	.....	.....	.....	Nickel 1.0
Die Casting Alloy..	3.3	85.4	11.0	.....	0.3	.....	....
Dutch Alloy.......	76.0	24.0	.....	.....	.....	.....	....
Fenton's Alloy.....	5.0	79.0	16.0	.....	.....	.....	....
Fontainemoreau's Bronze..........	7.0	92.0	.....	.....	.....	1.0	....
French Brass (potin jaune)..........	71.9	24.9	1.2	2.0	.....	.....	....
Gedge's Metal.....	60.0	38.5	.....	.....	.....	1.5	....
German Silver.....	50.0	29.0	.....	.....	.....	.....	Nickel 21.0
Graney's Bronze...	75.8	.....	8.6	15.6	.....	.....	....
Gun Metal (U. S.).	88.0	2.0	10.0	.....	.....	.....	....
Hamilton's Metal..	64.5	32.5	0.3	2.7	.....	.....	....
Harrington Bronze.	55.7	42.7	1.0	.....	.....	0.6	....
Jewelers' Gilding Alloy...........	94.0	6.0	.....	.....	.....	.....	....
Lap Alloy.........	12.5	87.5	.....	.....	.....	.....	....
Lumen Metal......	10.0	85.0	.....	.....	5.0	.....	....
Macht's Yellow Metal...........	57.0	43.0	.....	.....	.....	.....	....
Magnalium........	.....	.....	.....	.....	80.0	.....	Magnesium 20.0
Manganese Bronze.	58.5	41.0	.....	0.1	0.4	.....	Manganese to deoxidize
Monel Metal......	29.5	.....	.....	.....	.....	1.5	Nickel 69.0
Mosaic Gold.......	66.7	33.3	.....	.....	.....	.....	....
Muntz's Metal....	60.0	40.0	.....	.....	.....	.....	....
Naval Brass.......	62.0	37.0	1.0	.....	.....	.....	....
Oreide (French Gold)...........	90.0	10.0	.....	.....	.....	.....	....
Parson's White Brass...........	3.0	35.0	62.0	.....	.....	.....	....
Phosphor Bronze...	79.7	.....	10.0	9.5	.....	.....	Phosphorus 0.8
Pinchbeck.........	93.6	6.4	.....	.....	.....	.....	....
Plastic Bronze.....	64.0	30.0	5.0	.....	.....	.....	Nickel 1.0
Plumbic Bronze....	50.0	.....	.....	50.0	.....	.....	....
Prince's Metal.....	75.0	25.0	.....	.....	.....	.....	....
Red Metal.........	89.5	10.3	.....	0.2	.....	.....	....
Similor (Mannheim Gold)...........	85.0	10.0	5.0	.....	.....	.....	....
Sorrel's Alloy......	5.0	90.0	.....	.....	.....	5.0	....
Speculum Metal...	66.7	.....	33.3	.....	.....	.....	....
Sterro Metal.......	55.0	42.3	0.9	.....	.....	1.8	....
Talmi Gold........	90.7	8.3	.....	.....	.....	.....	Gold 1.0
Tissier's Metal.....	97.0	2.0	.....	.....	.....	.....	Arsenic 1.0
Tobin Bronze......	58.2	39.5	2.3	.....	.....	.....	....
Tombac...........	85.0	15.0	.....	.....	.....	.....	....
Tournay's Alloy....	82.5	17.5	.....	.....	.....	.....	....

From various sources. See also tables of Antimony Alloys, Fusible Alloys, etc.

Composition of Various Brasses by Color

Color	Copper	Zinc
Bluish gray	5	95
Ash gray	20	80
Silver white	30	70
Pale yellow	45	55
Yellow	67	33
Red yellow	55	45
Yellow red	85	15
Orange	99	1

From various sources.

Brass Solders

Copper	Zinc	Tin	Lead	Color	Properties
58	42	..	..	Red Yellow	Very strong
53	47	..	..	" "	Strong
50	50	..	..	" "	Medium
33	67	..	..	White	Easily Fusible
44	50	4	2	Gray	" "
57	28	15	..	White	White Solder

From Hiorn's "Mixed Metals."

Fusible Alloys

Name	Melting Point	Tin	Bis-muth	Lead	Cad-mium
Fusible Alloy	150° F.	1	4	2	1
Lipowitz's Alloy	158° F.	4	15	8	3
Wood's Alloy	160° F.	2	5	4	2
Fusible Alloy	187° F.	4	..	2	2
Onion's Alloy	197° F.	2	5	3	..
Newton's Alloy	202° F.	3	8	5	..
Clichet Alloy	221° F.	2	5	2	..
Rose's Alloy	230° F.	1	2	1	..

From Hiorn's "Mixed Metals."

Antimony Alloys

Name	Antimony	Lead	Tin	Zinc	Copper	Iron	Bismuth	Nickel
Type Metal	30.0	60.0	10.0	.....	.....	.....	.....	.....
Tutania Metal	25.0	.....	25.0	9.0	16.0	.....	25.0	.....
American Anti-friction Metal	18.4	80.0	.....	1.0	.....	0.6	.....	.....
Minofor Metal	18.2	.....	68.5	10.0	3.3	.....	.....	.....
Linotype Metal	16.0	79.0	5.0	.....	.....	.....	.....	.....
Monotype Metal	16.0	76.0	8.0	.....	.....	.....	.....	.....
Magnolia Metal	16.0	79.0	5.0	.....	.....	.....	.....	.....
Ashberry Metal	14.0	.....	80.0	1.0	2.0	.....	.....	3.0
White Metal	12.1	87.9	.....	.....	.....	.....	.....	.....
Stereotype Metal	11.8	83.7	4.0	.....	0.5	.....	.....	.....
Anti-friction Metal	11.7	88.3	.....	.....	.....	.....	.....	.....
Algiers Metal	10.0	.....	90.0	.....	.....	.....	.....	.....
Hard Babbitt Metal	9.3	.....	81.5	.....	9.2	.....	.....	.....
Metallic Packing	8.3	83.4	8.3	.....	.....	.....	.....	.....
Genuine Soft Babbitt Metal	8.0	.....	81.5	.....	4.0	.....	.....	.....
Queen's Metal	7.1	.....	88.5	0.9	3.5	.....	.....	.....
Britania Metal	7.0	.....	90.0	.....	3.0	.....	.....	.....
Electrotype Metal	4.0	92.0	4.0	.....	.....	.....	.....	.....

From various sources.

Copper-Tin Alloys

Copper	Tin	Specific Gravity	Color	Tensile Strength Lbs. per sq. in.	Authority	Use
100	0	8.921	Red	......	Marchand	Cast copper
49	1	8.564	"	......	Thurston	....
25	1	8.649	Reddish yellow	32,000	"	....
13	1	8.694	" "	28,500	"	....
10	1	.....	" "	32,093	Muschenbroek	Ordnance
9	1	8.669	Grayish yellow	26,860	Thurston	"
8	1	8.353	" "	26,011	Wade	"
7	1	8.648	" "	31.100	Thurston	Gun Metal
6	1	.....	" "	44,071	Muschenbroek	....
5	1	8.462	Yellowish red	34,048	Mallet	....
4	1	.....	" "	35,739	Muschenbroek	....
3	1	8.870	Reddish white	......	Riche	....
7	3	8.932	....	5,585	Thurston	Brittle
2	1	8.907	White	2,536	"	Mirrors
3	2	8.539	Dark gray	1,120	Mallet	....
1	1	8.790	Bluish white	......	Wade	....
4	5	8.300	Grayish white	......	Riche	....
2	3	8.132	" "	2,820	Thurston	Bell Metal
1	4	7.835	" "	6,775	Tomson	....
1	7	7.543	" "	3,798	"	....
1	9	7.490	" "	6,450	"	....
1	10	7.472	" "	......	Wade	....
1	12	7.417	" "	6,096	Thurston	....
1	89	7.305	" "	3,650	"	....
0	100	7.293	" "	3,500	"	....

Condensed from Hiorn's "Mixed Metals."

Copper-Zinc Alloys

Copper	Zinc	Specific Gravity	Color	Tensile Strengh lbs. per sq. in.	Authority	Use
10	1	8.605	Red yellow	27,104	Mallet	Tombac
9	1	8.607	" "	25,760	"	Oreide
8	1	8.633	" "	28,672	"	....
7	1	8.587	" "	29,568	"	....
6	1	8.710	" "	31,584	"	....
5	1	8.673	" "	32,600	"	....
4	1	8.650	Yellow red	32,928	Thurston	Ductile Metal
3	1	8.379	Yellow	29,344	Mallet	....
2	1	8.392	"	37,800	Thurston	Common Brass
3	2	8.363	"	50,450	"	Forging Metal
1	1	8.291	"	30,990	"	....
2	3	8.171	Silver white	......	Riche	....
3	5	7.974	" "	2,656	Thurston	....
1	2	7.859	" "	......	Millet	Brass Solder
4	9	7.811	" "	1,774	Thurston	Brittle
2	5	7.766	Ash gray	......	"	....
4	11	7.882	" "	1,792	Millet	Brittle
1	3	7.449	" "	......	"	"
1	4	7.371	" "	......	"	Buttons
1	5	7.136	Bluish gray	......	Thurston	Brittle
1	8	7.108	" "	......	"	"

Condensed from Hiorn's "Mixed Metals."

Combustion Data for Gases

Fuel	Lbs. Oxygen for 1 Lb. Fuel	Lbs. Air for 1 Lb. Fuel	Cu. Ft. Oxygen for 1 Cu. Ft. Fuel
Hydrogen.............	8.00	34.632	0.5
Methane..............	4.00	17.316	2.0
Ethylene..............	3.43	14.848	3.0
Acetylene..............	3.077	13.320	2.5
Carbon to CO_2........	2.66	11.517	...
Carbon to CO.........	1.33	5.759	...

From Moldenke, "Principles of Iron Founding."

Flame Temperatures

Fuel	Combustion in Air (Le Chatelier)	Combustion in Oxygen (after Richards)
Carbon to Carbon Monoxide.......	2,335° F.	6,045° F.
Carbon to Carbon Dioxide.........	3,700° F.	6,685° F.
Carbon Monoxide to Carbon Dioxide	3,810° F.	5,400° F.
Hydrogen to Water-vapor..........	3,585° F.	5,775° F.
Methane to Carbon Dioxide and Water-vapor..................	3,360° F.	5,760° F.
Ethylene to Carbon Dioxide and Water-vapor....................	3,735° F.	6,450° F.
Acetylene to Carbon Dioxide and Water-vapor....................	4,390° F.	8,030° F.

From Moldenke, "Principles of Iron Founding."

Physical and Chemical Data of Foundry Metals

Name	Symbol	Atomic Weight	Specific Gravity	Lbs. per Cu. Ft.	Melting Point DegreesF
Aluminum.............	Al	27	2.56	165	1,255
Antimony.............	Sb	120	6.71	419	1,165
Cadmium..............	Cd	112	8.60	536	610
Chromium.............	Cr	52	6.50	286	2,740
Copper...............	Cu	63.6	8.93	556	1,980
Gold.................	Au	197	19.32	1,206	1,945
Iron.................	Fe	56	7.86	485	2,770
Lead.................	Pb	207	11.37	710	620
Magnesium............	Mg	24	1.74	109	1,200
Manganese............	Mn	55	8.00	475	2,235
Molybdenum...........	Mo	96	8.60	540	4,530
Nickel...............	Ni	58.5	8.60	537	2,640
Platinum.............	Pt	195	21.50	1,330	3,190
Silver...............	Ag	108	10.53	657	1,760
Tin..................	Sn	119	7.29	459	450
Titanium.............	Ti	48	3.54	221	3,360
Tungsten.............	W	184	19.10	1,200	5,430
Vanadium.............	V	51	5.50	343	3,180
Zinc.................	Zn	65	7.15	440	785

From various sources.

DIGEST OF SCRAP SPECIFICATIONS ADOPTED BY THE AMERICAN FOUNDRYMEN'S ASSOCIATION

General: All scrap to be bought and sold on basis of net ton of 2,000 lbs. Variations in weights subject to regulations of authorized weighing associations operating in territory of delivery. On rejection, if not up to specifications, seller to pay demurrage and return freight.

CAST IRON SCRAP: No. 1 Machinery Scrap. To be first quality material, every piece to show evidence of machining. No piece over 100 lbs. and not over 24″ long or wide. No railroad or other classes of scrap mentioned hereafter, or any burnt iron will be accepted under machinery scrap. No. 1 heavy—pieces over 1″ section. No. 1 Medium—between ½″ and 1″ section. No. 1 Light—under ½″ section.

No. 2 Machinery Scrap. To be first quality material every piece to show evidence of machining. Shall be in unbroken state. Same restrictions and section divisions as in No. 1 Machinery.

No. 3 Rough Scrap. Cast scrap such as columns, pipe, plates and rough castings broken to cupola size—no piece over 100 lbs. and over 24″ long or wide. Section divisions into Heavy, Medium and Light as in No. 1 Machinery.

No. 4 Rough Scrap. Pieces in unbroken state. Quality requirements and section divisions as in No. 3 Rough Scrap.

No. 5 Machinery Scrap. Burnt machinery scrap of miscellaneous character, but no burnt material of other classifications.

No. 1 Stove Plate Scrap. Best class clean stove plate. Free from malleable iron and steel parts. No grates, burnt iron of any description, railroad, or other classes of scrap permitted.

No. 2 Stove Plate Scrap. All stove parts not in No. 1. No burnt material of any description, railroad or other class scrap permitted.

No. 3 Stove Plate Scrap. Burnt stove parts only.

No. 1 Agricultural Scrap. Cast iron parts of agricultural machinery, free from steel, malleable iron, chilled iron (plow points) and all burnt iron.

No. 2 Agricultural Scrap. Chilled iron parts of agricultural machinery, free from steel, malleable iron and burnt iron of all kinds.

No. 1 Railroad Scrap. Only chilled M. C. B. car wheels.

No. 2 Railroad Scrap. Miscellaneous cast iron car wheels not in No. 1.

No. 3 Railroad Scrap. Only gray iron brake shoes free from steel backs and inserts.

No. 4 Railroad Scrap. Steel back and insert brake shoes of driver and car types. No brake shoes of No. 3 classification.

No. 5 Railroad Scrap. Railroad burnt iron of every description.

No. 6 Railroad Scrap. Unburnt railroad grate bars and grate bar rests. Also journal boxes with steel parts removed.

No. 1 Radiator Scrap. Broken radiator casting free from scale, rust and excessive corrosion. All steel malleable and other parts removed.

No. 2 Radiator Scrap. Unbroken radiator castings. Same restrictions as in No. 1.

MALLEABLE CAST IRON SCRAP. All material under this classification must have gone through the regular annealing process for malleable castings.

Automobile Malleable Scrap. Only malleable cast iron automobile parts free from steel and gray iron parts. No railroad malleable, pipe fittings, agricultural parts, etc., permitted.

Railroad Malleable Scrap. Only railroad malleable No. 1—pieces not over 3/8″ section or 24″ long or wide. No. 2—pieces between 3/8″ and 3/4″ section and not over 24″ long or wide. No. 3—pieces over 3/4″ section and over 24″ long or wide. No agricultural malleable, pipe fittings, etc., permitted.

Agricultural Malleable Scrap. Malleable cast iron parts of agricultural machinery. Free from steel and cast iron. Same section divisions as in railroad malleable scrap. No pipe fittings, valves, etc., permitted.

Miscellaneous Malleable Scrap. Valves, pipe fittings and all other malleable scrap not covered in previous classifications.

HEAVY OPEN HEARTH STEEL SCRAP. Must not include pieces that are covered with excessive rust or show serious corrosion.

No. 1 Heavy Structural Steel Scrap. All Structural shapes 1/4″ and over. Not over 5 feet long and 18″ wide, charging box size. No piece over 25 lbs. Free from all iron.

No. 2 Heavy Structural Steel Scrap. All structural shapes ½″ and over. Pieces over 5 feet long and 18″ wide. No piece over 600 lbs. Free from all iron and bent and twisted pieces.

No. 3 Steel Rails. Standard sections 50 lbs. and over. Not over 5 feet long or 18″ wide. No frogs, switches, guard rails and crossing rails.

No. 4 Steel Rails. Standard sections under 50 lbs. Otherwise same as No. 3 Steel Rails.

No. 5 Steel Rails. Standard sections 50 lbs. and over, not cut to charging box size. Otherwise same as No. 3 Steel Rails.

No. 6 Steel Rails. Standard sections under 50 lbs. and not cut to charging box size. Otherwise same as No. 3 Steel Rails.

No. 7 Heavy Steel Scrap. Guard rails, switches, crossing rails and frogs. Cut apart to charging box size. No iron plates.

No. 8 Heavy Steel Scrap. No. 7 material over 5 feet long and 24″ wide. No bent, curved and twisted pieces.

No. 9 Heavy Steel Scrap. Locomotive drivers, engine truck and coach tires 36″ and over inside diameter.

No. 10 Heavy Steel Scrap. Miscellaneous steel tires under 36″ inside diameter.

No. 11 Steel Tires. Nos. 9 and 10 broken to charging box size.

No. 12 Heavy Steel Scrap. Miscellaneous mild steel castings between 25 and 300 lbs. Charging box size and containing no malleable or cast iron.

No. 13 Heavy Steel Scrap. Cast Steel couplers, knuckles, coupler heads and drawbars. Free from iron yokes, etc.

LIGHT OPEN HEARTH STEEL SCRAP. Must be free from excessive rust or corrosion.

No. 1 Light Steel Scrap. Steel springs not under ⅜″ thickness or diameter. Elliptical springs cut apart. No plates permitted.

No. 2 Light Steel Scrap. Miscellaneous steel shapes, crop ends, fish plates, etc. Not over 25 lbs. Charging box size. No bundle scrap or iron.

No. 3 Light Steel Scrap. Turnings and borings of wrought iron and mild steel. Free from malleable iron, brass, high carbon steel borings and other metals. Clean and free from dirt and lumps.

No. 4 Light Steel Scrap. Turnings and borings of high carbon steel with same restrictions as in No. 3.

No. 5 Light Steel Scrap. Bundled scrap and light steel scrap under ¼″ section. No galvanized or tinned material permitted. Charging box size.

No. 6 Light Steel Scrap. Miscellaneous cast steel not covered in above classifications. Between 5 and 25 lbs. Free from malleable and cast iron.

CONVERTER STEEL SCRAP. Must be free from excessive rust or corrosion and not over 24″ wide or long (cupola size).

No. 1 Converter Scrap. Mild open hearth scrap 25 to 200 lbs., structural shapes, forgings, crop ends.

No. 2 Converter Scrap. Open hearth high carbon scrap and hard steel rails. Between 25 and 200 lbs.

No. 3 Converter Scrap. Miscellaneous mild steel castings between 25 and 200 lbs. Free from malleable and cast iron.

No. 4 Converter Scrap. Miscellaneous mild steel castings under 25 lbs. Free from malleable and cast iron.

No. 5 Converter Scrap. Miscellaneous steel tires, broken.

No. 6 Converter Scrap. Mild open hearth steel scrap, punchings, etc. Pieces between 5 and 25 lbs. Clean.

No. 7 Converter Scrap. Steel Springs not under ⅜″ thick or diameter. Elliptical Springs cut apart.

CRUCIBLE STEEL SCRAP. Six classifications.

ELECTRIC FURNACE STEEL SCRAP. Eleven classifications.

The above are of interest to a very limited number of foundries, and are therefore omitted in this digest.

From "Transactions of American Foundrymen's Association."

Factors of Safety in Cast Iron Construction

A dead load	4
A live or varying load of one kind	6
Equal alternate stresses of different kind	10
Varying loads and shocks	15

From Unwin, "Elements of Machine Design."

PREPARATION OF SAMPLES FOR ANALYSIS

The following methods of preparing samples for analysis are intended to aid the Foundryman in getting reliable results for his mixture making and melting practice. Unless the sample is representative of the shipment, the analysis is practically worthless.

Pig Iron

Select one pig at random from each 4 tons of iron—10 pigs representing a unit for sampling (40 tons, or the usual car load). Cleanse the surface of each pig with a stiff wire brush or in any manner which will remove all loose sand and prevent introducing deleterious matter into the sample as it is taken.

Remove the skin with an emery wheel down to clean metal at the center of the upper face of each pig, and brush off the surface carefully. Take drillings with a ¼″ twist drill, from top to bottom of each pig, starting from the center of the cleared spot and stopping when the point of the drill appears below. One hole only in each pig.

Use suitable precautions to prevent escape of fine particles during the drilling. To do this best, clamp a disk of clean sheet metal on the pig after the skin has been removed. The disk shall have a hole in the center just large enough to receive the drill. Most of the drillings will accumulate on top of the disk and can be brushed off after the drill has been withdrawn. The rest is caught by turning the pig bottom side up on a receptacle to collect what remained in the hole.

Cast Iron

In accordance with the Specifications for gray iron castings, of the American Society for Testing Materials, two standard test bars are cast from each heat at the beginning, and again three at the end of pouring. One bar from each set having been broken, one end of each next the fracture is thoroughly cleaned and the outer skin removed to clean metal a sufficient distance back. The piece is now put into the lathe or milling machine and chips taken across the whole face of the bar until not less than ¼ lb. has been removed. Take same amount from each of the other bars. Clamp so that suitable devices for collecting the sample can be attached, and run machine slow enough to prevent loss of fine particles. Mix all chips together well and send to laboratory for analysis.

Coke

Take sample from exposed surface of car, by knocking off with hammer a piece approximately the size of a walnut, every 18″ along three lines running from one end of car to the other One line through centre of car, and other two lines 2 feet from respective sides of the car. With hammer 18″ long, measurements are simple by turning it over and breaking off a piece where the head rests each time and regardless of appearance of coke.

Total quantity to be not less than 2 pecks. Crush on steel plate with hammer or sledge, avoiding all rubbing action. Pass through screen having 4 meshes to linear inch. Mix sample on strong, closely woven cloth about 5 feet square, by raising four sides of cloth successively and rolling coke over to mix well. Lift four corners of cloth to make conical pile. Flatten apex of pile and divide into quarters of equal size. Remove two diagonally opposite quarters and brush space clean. Mix remaining two quarters again, cone the pile, quarter and discard two diagonally opposite quarters, and repeat until sample remaining runs not less than 5 lbs. Put in suitable container and ship to laboratory for analysis.

When a moisture determination is to be made a special method is used, the above being for the ordinary constituents only.

From "Yearbook American Society for Testing Materials."

STANDARD SPECIFICATIONS FOR GRAY IRON CASTINGS

(Digest)

(1) Cupola Metal, unless air furnace iron is specified particularly.

(2) Chemical properties: Light and Medium castings, sulphur not over 0.10%. Heavy castings, sulphur not over 0.12%.

(3) Classifications: Light castings have less than ½″ section. Heavy castings have sections 2″ thick and over. Medium castings are between these.

(4) Physical Properties: Transverse test. Minimum breaking strength of "Arbitration Bar" shall be: Light castings, 2,500 lbs.; medium castings, 2,900 lbs.; heavy castings, 3,300 lbs. Deflection in no case under 0.10 in.
Tensile test (where specified): Light castings, not less than 18,000 lbs. per sq. in.; medium castings, 21,000 lbs. per sq. in.; heavy castings, 24,000 lbs. per sq. in.

(5) Arbitration Bar: This is 1¼″ diameter and 15″ long. Cast in vertical position in dry sand mold, with top pour. Transverse test, bar on supports 12″ apart. Tensile test not recommended, but if made can use broken pieces of transverse bar with ends suitably turned to threads and middle portion 0.8″ diameter for 1″ including fillets.

(6) Number of test bars: Two sets of two bars from beginning and same from end of each heat. Where over 20 tons, additional set of two bars for every extra 20 tons or fraction thereof. In case of change of mixture during heat, an extra set of bars for every mixture other than the regular one. Each set of two bars in single mold. Bars not to be rumbled or otherwise treated, but simply brushed off before testing.

(7) Speed of testing: Rate of application of load from 20 to 40 seconds for a deflection of 0.10 in.

(8) Samples for analysis: Broken pieces of Arbitration Bar to be used for sulphur analysis. One determination for each mold. In case of dispute, standards of U. S. Bureau of Standards to be used for comparison.

(9) Finish: Castings true to pattern. Free from cracks, flaws and excessive shrinkage.

(10) Inspection: All reasonable facilities to be afforded purchaser to satisfy himself that he gets what he specifies. Inspection and tests if possible prior to shipment.

From "Yearbook American Society for Testing Materials."

Units of Measure

Acre = 208.71 feet square = 43,560 sq. ft. = 4,840 sq. yds. = 0.404687 Hectares = 4,046.87 sq. meters.
Barrel = 196 lbs. (Flour) = 42 Gal. Oil (Standard Oil Co.)
Board Foot = one square foot, one inch thick.
Bushel = 4 pecks = 32 quarts = 2,150.42 cu. in. = 1.24446 cu.ft. = 35.23928 liters.
Cable (Cable length) = 720 ft. = 120 fathoms = 219.457 meters.
Chain = 100 ft. = 100 links = 30.48 meters.
Cord (of wood) = 4 ft. x 4 ft. x 8 ft. = 128 cu. ft. = 3.625 cu. meters.
Dram (apothecary) = 3 scruples = 60 grains = 3.888 grammes.
Fathom = 6 ft. = 1.829 meters.
Foot = 12 inches.
Furlong = 660 ft. = 40 rods, perches or poles = 1/8 mile = 201.17 meters.
Gallon = 231 cu. in. = 3.78543 liters = 3,785.43 cu. centimeters.
Gill = 1/4 pint.
Grain = 0.0648 grammes = 64.8 milligrammes.
Gramme = 15.43 grains.
Hogshead = 63 gallons = 2 barrels (31.5 gallons capacity) = 238.48 Liters.
Inch = 2.54 centimeters = 25.4 millimeters.
Karat = 200 milligrammes = 0.2 grammes = 3.0865 grains.
Kilogramme = 1,000 grammes = 2.20462 pounds avd.
Kilometer = 1,000 meters = 3,280.83 ft. = 0.62137 miles.
Knot (Nautical or geographical mile) = 6,080.2 ft. = 1.15155 miles = 1.85325 kilometers = 1 minute of earth's circumference.
League = 15,840 ft. = 3 miles = 4.828 kilometers.
Link = one hundredth of measuring chain = 12 in. (Engineer's chain) = 7.92 in. (Surveyor's chain) = 20 centimeters (Metric chain).
Liter = 1,000 cu. centimeters = 61.023 cu. in. = 0.0353 cu. ft. = 2.1134 liquid pints = 0.2642 gallons.
Meter = 39.37 inches = 3.28 ft.
Mile = 5,280 ft. = 1,760 yards. A square mile equals 640 acres = 2.59 sq. kilometers.
Milligram = 0.001 grammes = 0.015432 grains.
Millimeter = 0.001 meters = 0.03937 inches.
Ounce, Apothecary. Same as troy ounce = 480 grains = 31.104 grammes. Avoirdupois = 437.5 grains = 28.35 grammes = 0.9115 ounce troy or apothecary. Troy (for gold and silver) = 480 grains = 20 pennyweight = 31.104 grammes = 1.097 ounces avd.
Peck = 0.25 bushels = 8.81 liters.
Pennyweight = 24 grains = 1.555 grammes.
Pint, Liquid = 0.125 gallons = 0.4732 liters. Dry = 0.5 quarts = 0.5506 liters.
Pipe or Butt = 126 gallons = 2 hogsheads = 476.96 liters.
Pounds, Avoirdupois = 7,000 grains = 16 ounces (avd.) = 0.4536 kilogrammes. Troy or Apothecary = 5,760 grains = 12 ounces = 0.3732 kilogrammes.
Quart, Liquid = 0.25 gallons = 0.94634 liters. Dry = 0.03125 bushels = 67.2 cu. in. = 1.1 liters.
Rod or *Perch* or *Pole* = 16.5 ft. = 5.5 yards = 5.0292 meters.
Rood = 0.25 acres = 40 sq. rods = 1,210 sq. yds. = 1,011.72 sq. meters.
Scruple = 20 grains = 1.296 grammes.
Section of land = 1 mile square = 640 acres.
Stone = 14 pounds (avd.) = 6.35 kilogrammes.
Ton (gross) Displacement of water = 35.88 cu. ft. = 1,016 cu. meters. (gross or long) = 2,240 lbs. (avd.) = 1.12 short or net tons = 1,016.05 kilogrammes = 1.01605 metric tons. (net or short) = 2,000 lbs. (avd.) = 20 hundredweight = 907.185 kilogrammes = 0.907185 metric tons = 0.892857 long tons. (metric) = 2,204.62 pounds (avd.) = 1.10231 net tons = 0.9842 long tons = 1,000 kilogrammes.
Cubic yard = 27 cu. ft. = 46,656 cu. in. = 0.76456 cu. meters. Square yard = 9 sq. ft. = 1,296 sq. in. = 0.836 sq. meters. Yard = 3 feet = 36 inches = 0.9144 meters.

From Lefax Data Sheets.

Temperature Conversion Formulae

To change from Fahrenheit scale to Centigrade:

Subtract 32, multiply remainder by 5 and divide by 9:
$(F^\circ - 32)\ 5 \div 9 = C^\circ$.

Centigrade to Fahrenheit:

Multiply by 9, divide product by 5, add 32 to quotient:
$(C^\circ \times 9 \div 5) + 32 = F^\circ$.

Fahrenheit to Réaumur:

Subtract 32, multiply remainder by 4 and divide by 9:
$(F^\circ - 32)\ 4 \div 9 = R^\circ$.

Réaumur to Fahrenheit:

Multiply by 9, divide product by 4, add 32 to quotient:
$(R^\circ \times 9 \div 4) + 32 = F^\circ$.

Weight of Gases

Name	Symbol	Specific Gravity	Lbs. per Cu. Ft.	Cu. Ft. per Lb.
Air		1.000	0.0807	12.387
Oxygen	O	1.105	0.0892	11.204
Nitrogen	N	0.970	0.0783	12.753
Hydrogen	H	0.0696	0.00562	178.830
Nitric Oxide	NO	1.038	0.0838	11.933
Nitrous Oxide	N^2O	1.522	0.1229	8.140
Carbon Monoxide	CO	0.968	0.0780	12.804
Carbon Dioxide	CO^2	1.520	0.1227	8.101
Sulphur Dioxide	SO^2	2.213	0.1786	5.590
Ammonia	NH^3	0.590	0.0476	21.020
Acetylene	C^2H^2	0.899	0.0725	13.793
Methane	CH^4	0.554	0.0447	22.350
Natural Gas	.....	0.520	0.0394	25.140
Ethylene	C^2H^4	0.969	0.0780	12.580

From various sources.

Metric Conversion Table

Millimeters × 0.03937 = Inches.
Millimeters ÷ 25.4 = Inches.
Centimeters × 0.3937 = Inches.
Centimeters ÷ 2.54 = Inches.
Meters × 39.37 = Inches.
Meters × 3.281 = Feet.
Meters × 1.094 = Yards.
Kilometers × 0.621 = Miles.
Kilometers ÷ 1.6093 = Miles.
Square Millimeters × 0.00155 = Sq. Inches.
Square Millimeters ÷ 645.1 = Sq. Inches.
Square Centimeters × 0.155 = Sq. Inches.
Square Centimeters ÷ 6.451 = Sq. Inches.
Square Meters × 10.764 = Sq. Feet.
Square Kilometers × 247.1 = Acres.
Hectare × 2.471 = Acres.
Cubic Centimeters ÷ 16.383 = Cu. Inches.
Cubic Meters × 35.315 = Cu. Feet.
Cubic Meters × 1.308 = Cu. Yards
Cubic Meters × 264.2 = Gallons (231 cu. in.).
Liters × 61.022 = Cu. Inches.
Liters × 0.2642 = Gallons.
Liters ÷ 3.785 = Gallons.
Liters ÷ 28.316 = Cu. Feet.
Hectoliters × 3.531 = Cu. Feet.
Hectoliters × 2.84 = Bushels (2,150.42 cu. in.).
Hectoliters × 0.131 = Cu. Yards.
Hectoliters ÷ 26.42 = Gallons.
Grammes × 15.432 = Grains.
Grammes ÷ 28.35 = Ounces Adv.
Grammes per Cu. Cent. ÷ 27.7 = Lbs. per Cu. In.
Kilogrammes × 2.2046 = Pounds.
Kilogrammes × 35.3 = Ounces Adv.
Kilogrammes ÷ 907.2 = Tons (2,000 Lbs.).
Kilogr. per Sq. Cent. × 14.223 = Lbs. per Sq. In.
Kilogramme-meters × 7.233 = Foot-pounds.
Kilogramme per Meter × 0.672 = Pounds per Foot.
Kilogramme per Cu. Meter × 0.062 = Pounds per Cu. Ft.
Kilowatt × 1.34 = Horse Power.
Watts ÷ 746 = Horse Power.
Watts × 0.7373 = Foot Pounds per Second.
Calorie × 3.968 = British Thermal Unit.
Cheval Vapeur × 0.9863 = Horse Power.

From Arrangement by C. W. Hunt, New York.

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